AFRL-RX-TY-TP-2010-0048

ADVANCED INTEGRATED POWER SYSTEM – PROGRAMMATIC REVIEW (BRIEFING SLIDES)

Marcus D. Smith

Air Force Research Laboratory
139 Barnes Drive, Suite 2
Tyndall Air Force Base, FL 32403-5323

Contract No. FA4819-09-C-0031

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139 Barnes Drive, Suite 2

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14. ABSTRACT

AFRL's deployed base smart grid project named AIPS (Advanced Integrated Power System) is a smart grid test bed where proposed modifications to the existing deployed base power grid infrastructure are tested and evaluated. Adding intelligent control systems in addition to alternative and renewable power sources distributed throughout the grid requires careful testing. AIPS is fully instrumented to evaluate the impact these technologies will have on the deployed base power grid. Modifications to the traditional grid infrastructure are also evaluated since these modifications are necessary to implement important smart grid capabilities such as automated integration of renewable and alternative energy sources, priority power routing, on demand load shedding, power quality compensation, advanced energy storage systems, seamless transition to backup supplies, peak load management, and grid master control shared by multiple dispersed controllers. These technologies increase grid reliability as well as making the deployed grid less vulnerable to attack.

15. SUBJECT TERMS

Smart grid, microgrid, intelligent grid management, renewable power source, distributed generation, deployed base power system, priority power routing

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Advanced Integrated Power System (Microgrid Test Bed)

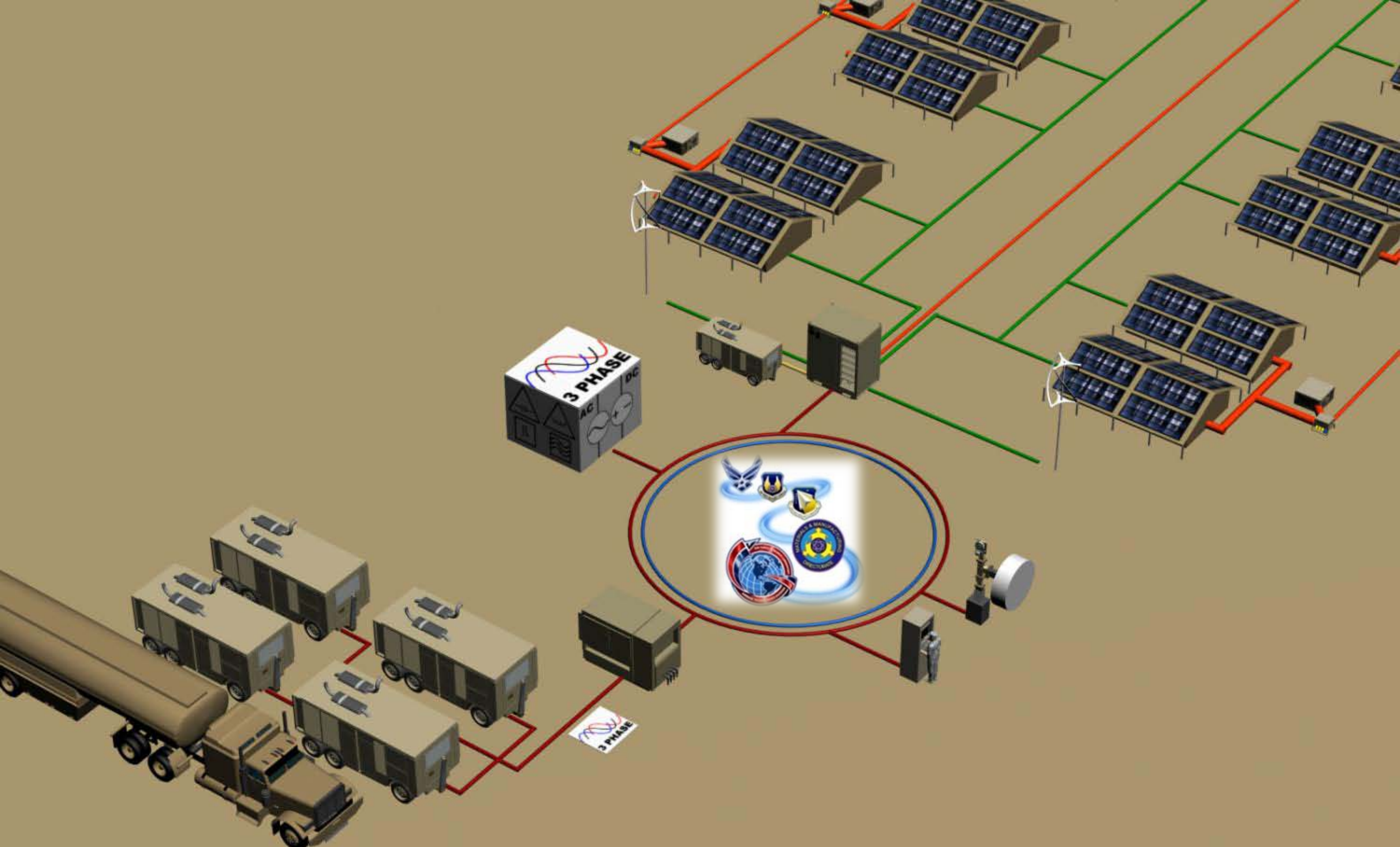
2010

Marcus Smith

Engineering Lead (Energy Group)

AFRL/RXQD

Air Force Research Laboratory

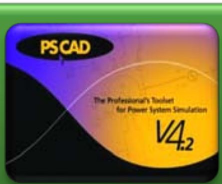


Advanced Integrated Power System (AIPS)

AIPS Programmatic Review

AIPS Goals and Strategy

Capabilities to be Evaluated AIPS Test Bed

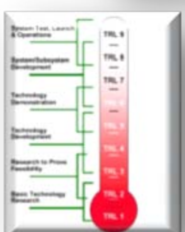


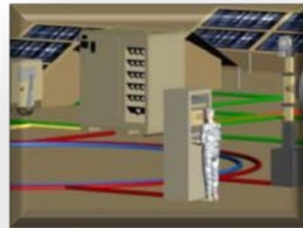
System Modeling

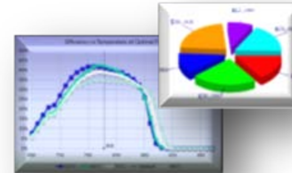
Phase 1 AIPS Components

Partnerships and Collaborations

AIPS Testing Strategy







Tech Evaluation
- Portability
- TRL Level
- Warfighter Need
- Define Requirements with AFCESA

Modeling
- Simulation of Stand Alone System
- Simulate Potential Impact on Microgrid
- Power Density Expectation (Watts/Kg)

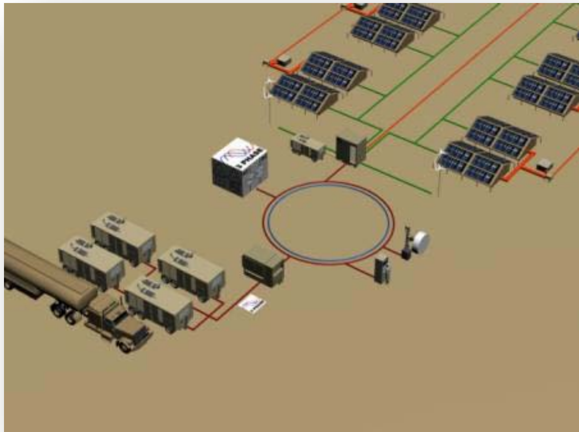
Isolated Testing
- Power Generation Profile*
- Power Quality Analysis
- Calorimeter Chamber Testing (Temperature & Humidity)

Integration Testing
- Microgrid Power Quality Analysis
- Plug & Play (Is the System Simple to Use?)
- Performance Testing Over Full Spectrum of Weather Conditions (At Least 1 Full Year)
- Loss Budget Calculations (Includes Cable Losses, Passive and Active Components, etc.)

Reporting
- Engineering Technical Letter
- Microgrid Component Recommendation
- Published Set of Integration Standards
- Paper on Microgrid Control Techniques
- Database of Measured Performance of Microgrid Components

* Power Source
# Computer hardware

AIPS System Goals

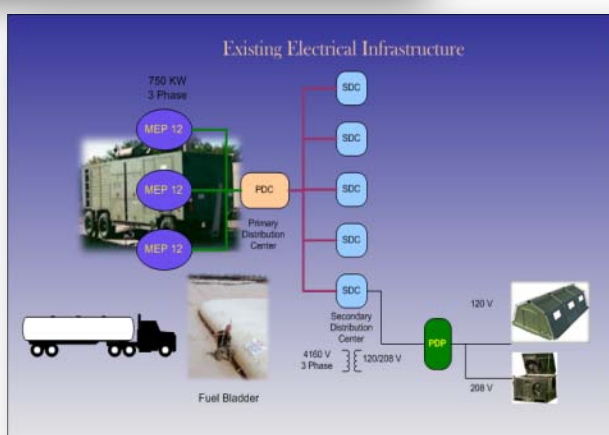


- Create a fully instrumented microgrid test bed where new energy technologies and control methods will be demonstrated and evaluated before deployment.

- Development of a set of Integration Standards that describes the method for Integrating, conditioning, and controlling renewable & alternative power sources in a deployed air base microgrid.

- Build and program microprocessor based field controllers to automate power routing, load shedding, power conditioning, etc.

Current Power System



- Power plant consists of a MEP 12 (750 kW) generator farm. These units are Placed away from the main camp due to noise and fumes.
- Each Generator Consumes 55 Gal/hr of JP8. Fuel is placed next to the generators in large fuel bladders. This makes the primary power source vulnerable.
- Power branches out from the generator farm in one direction.

Smart Grid Power Routing & Self Healing

- Survivability & redundancy for assured power is accomplished by using Inter-connected smart controllers to route remaining power resources around damaged portions of the grid.

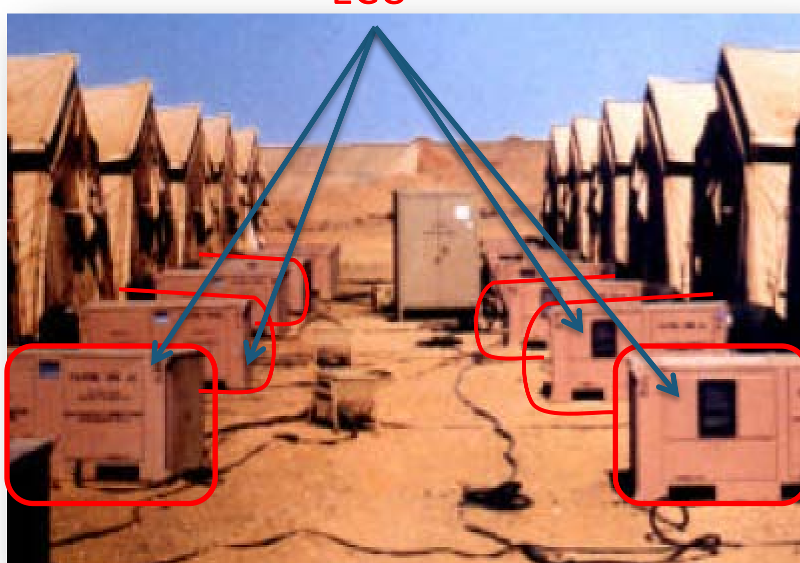
- Backup supplies are brought online and energy storage reserves are made available to insure power is available to critical loads.

- Distributed power sources throughout the grid minimize the potential for all of the base’s power generation capability being destroyed in a single attack.

Triage Load Shedding

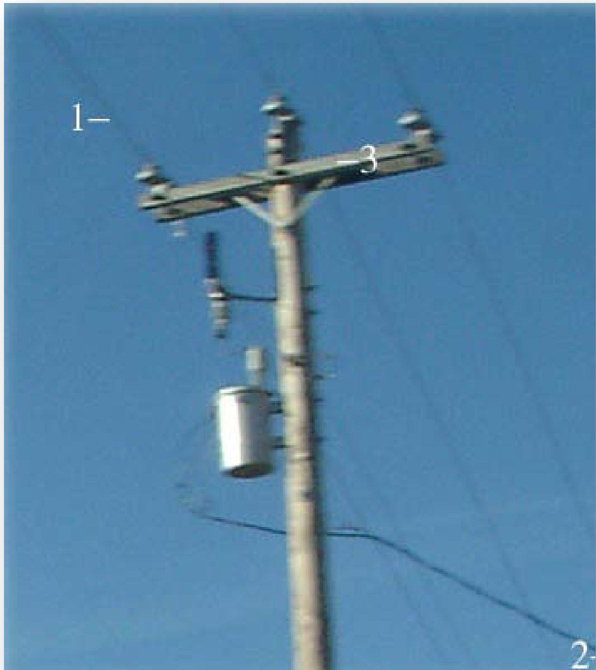
- ECUs (Environmental Conditioning Unit) consume ~70 % of available base power.
- These units could be temporarily disconnected from the microgrid using smart controllers and addressable breakers to increase available power to priority loads such as flight ops, perimeter security, etc.

ECU



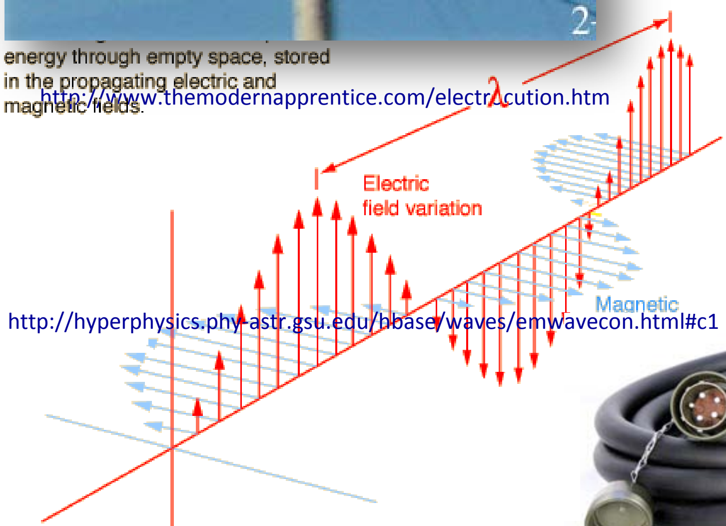
Flightline

Communication Over Power Lines



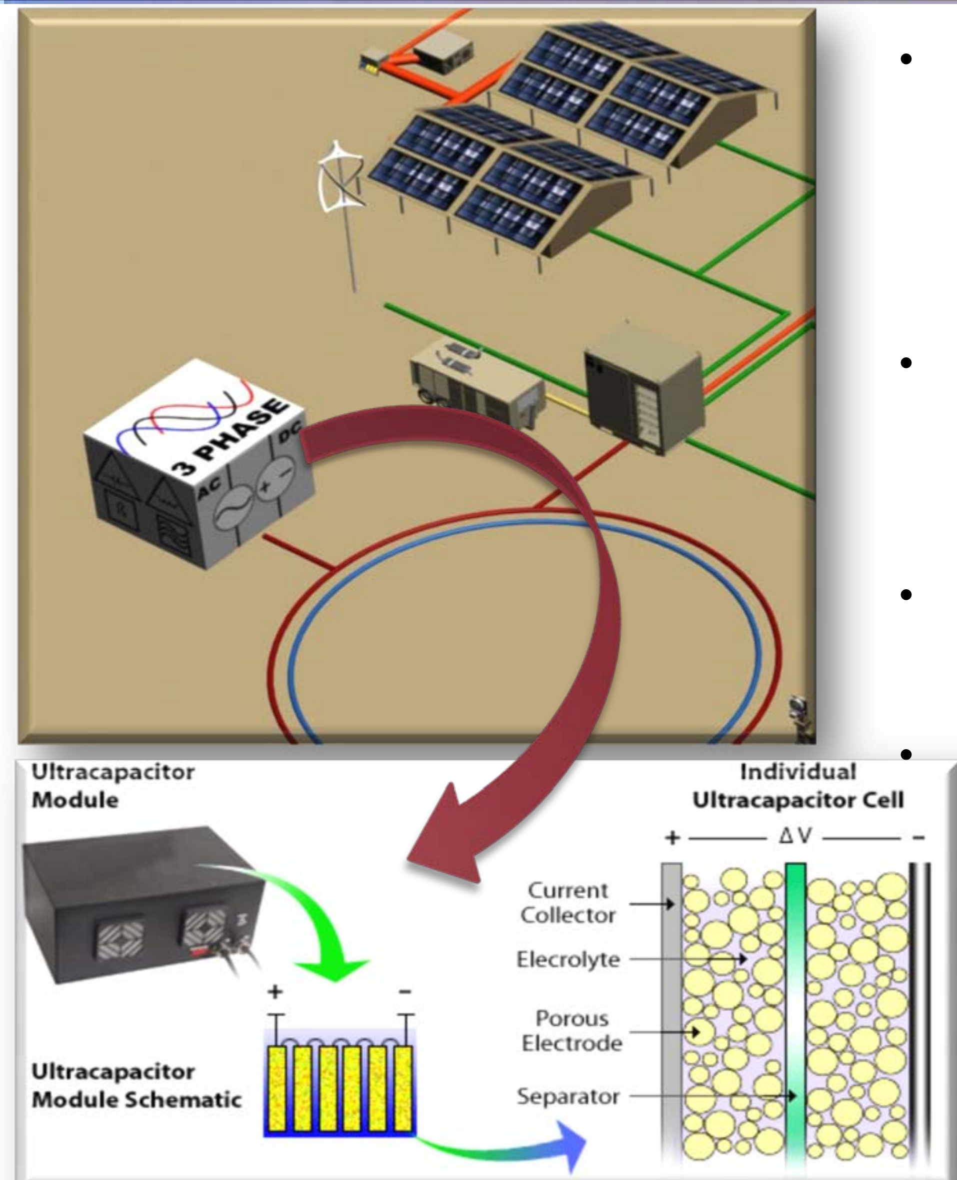
- Communication between grid elements is vital since automated decisions are based on available resources .
- Microgrid components communicate their status and capability to the microgrid controller.
- The microgrid controller transmits control signals and collects sensor data utilizing the power cables already in place.
  - This approach reduces infrastructure and eliminates potential signal conflicts presented by current wireless communication solutions.
  - Power companies use this type of technology to read power meters remotely. Adapting this technology to our need is a key research area for AIPS.

http://www.themodernapprentice.com/electrocution.htm



http://hyperphysics.phy-astr.gsu.edu/hbase/waves/emwavecon.html#c1

Power Quality Improve System Efficiency

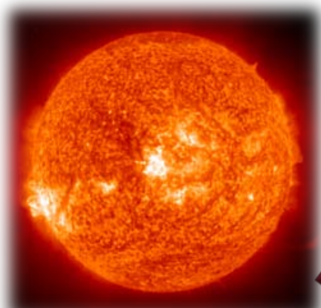


http://www.nrel.gov/vehiclesandfuels/energystorage/images/diagram_ultracap.gif

- Poor power quality can damage sensitive equipment, shorten the life of some systems, produce waste heat, and reduce the efficiency of the overall grid requiring more power production.
- DC power producers such as solar PV material must be inverted to AC in order to use the power elsewhere in the microgrid.
- This requires phase and voltage matching to prevent poor power quality.
- Noise filtering and other power quality correction approaches will be analyzed and the best solutions recommended to the CE community.

Energy Storage & Peak Load Management

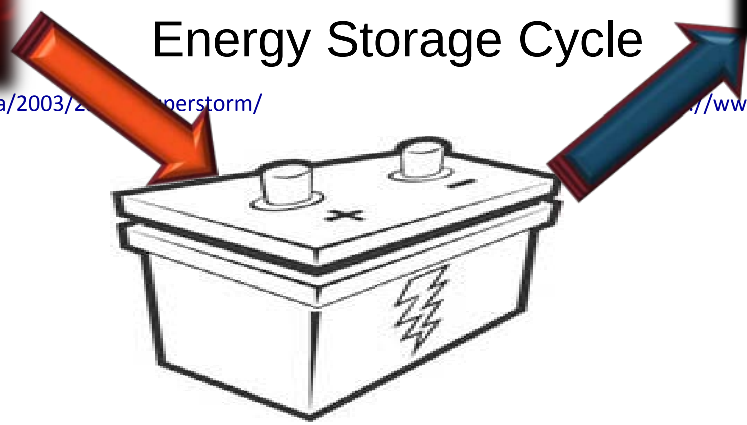
- Renewable power sources such as solar and wind produce electricity sporadically throughout the day and night.
- High density energy storage devices are necessary to provide predictable power when it is needed.
- Peak power requirements such as large load starts that would normally require the use of additional generators can be met using the power stored by renewable power sources.



http://science.nasa.gov/science-news/science-at-nasa/2003/2 ... perstorm/

Energy Storage Cycle

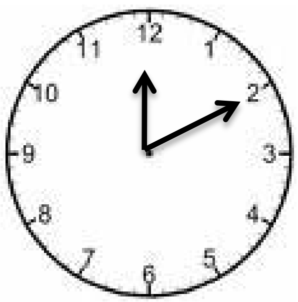
...//www.nasa.gov/worldbook/moon_worldbook.html

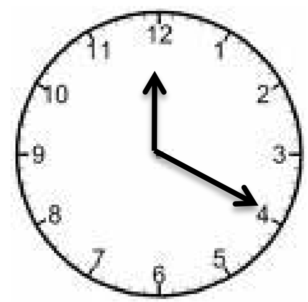


http://www.fotosearch.com/photos-images/battery.html

Smart Control Functions Reduce Power Requirements

- Large devices such as ECUs (Environmental Control Units), welding equipment, 3 phase motors, etc. use up to 3 times the normal operating power at start up (Due to Large Inrush Currents).
- Staggering large load start times will reduce the peak power requirement which reduces the number of generators needed.



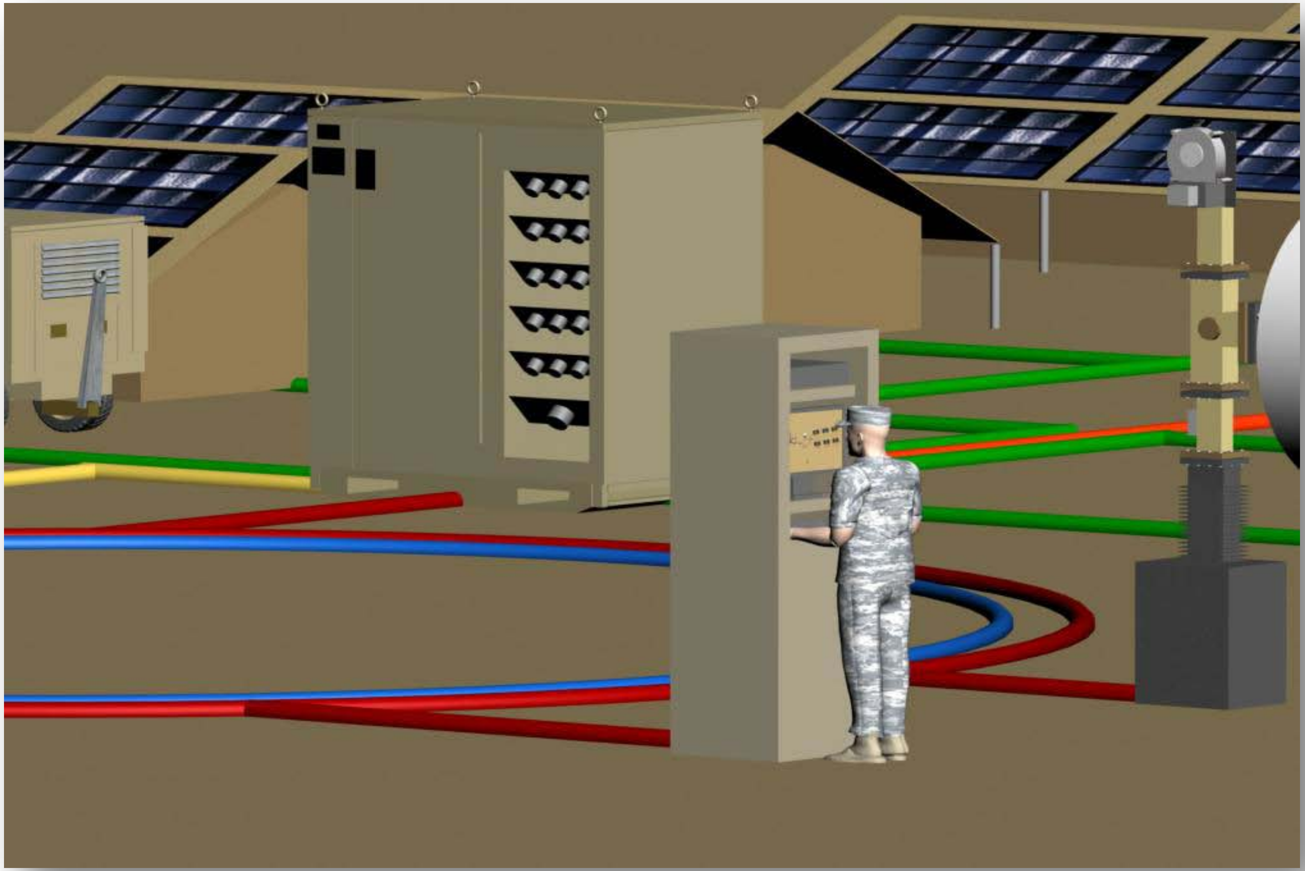


ECU #1

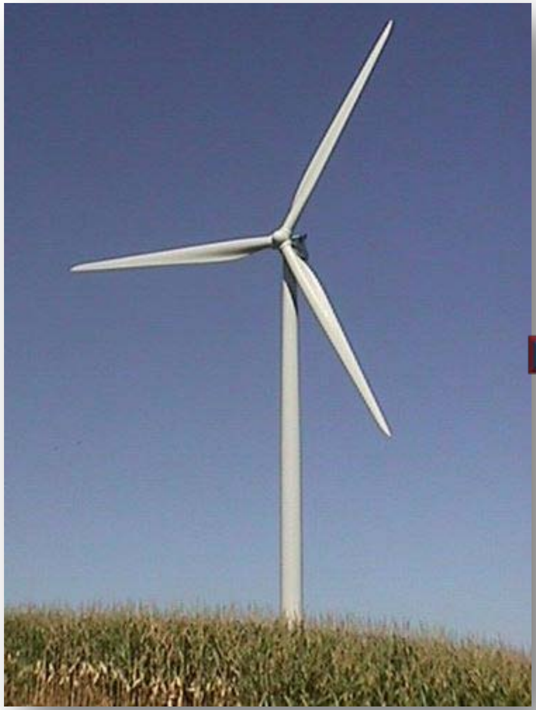
ECU #2

System at a Glance Control & Health Monitoring

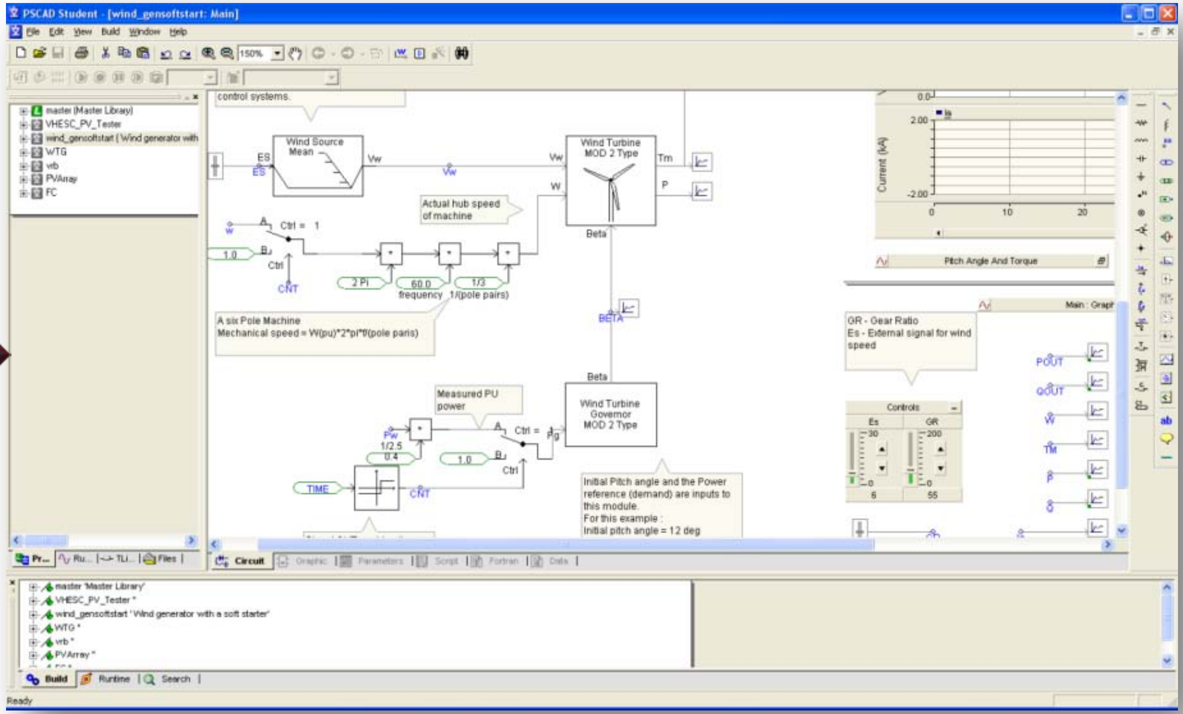
- The smart grid user interface enables the base power management team to instantly determine the health of the microgrid and make instantaneous changes.
- Changes to the management and distribution of the microgrid are implemented by a simple touch of the screen.



System Modeling Streamlines Grid Compatibility Testing



http://www-personal.umich.edu/~dopila/research.html



- Microgrid system component software models will be compatible with PSCAD (Power Systems Computer Assisted Drafting). This requirement will enable the components to be modeled as a part of the whole microgrid which should indicate any potential grid compatibility issues.
- The microgrid system model is a valuable research tool because design concepts can be virtually evaluated before the first piece of hardware is made. This model will also help in determining power quality correction measures that may need to be implemented.

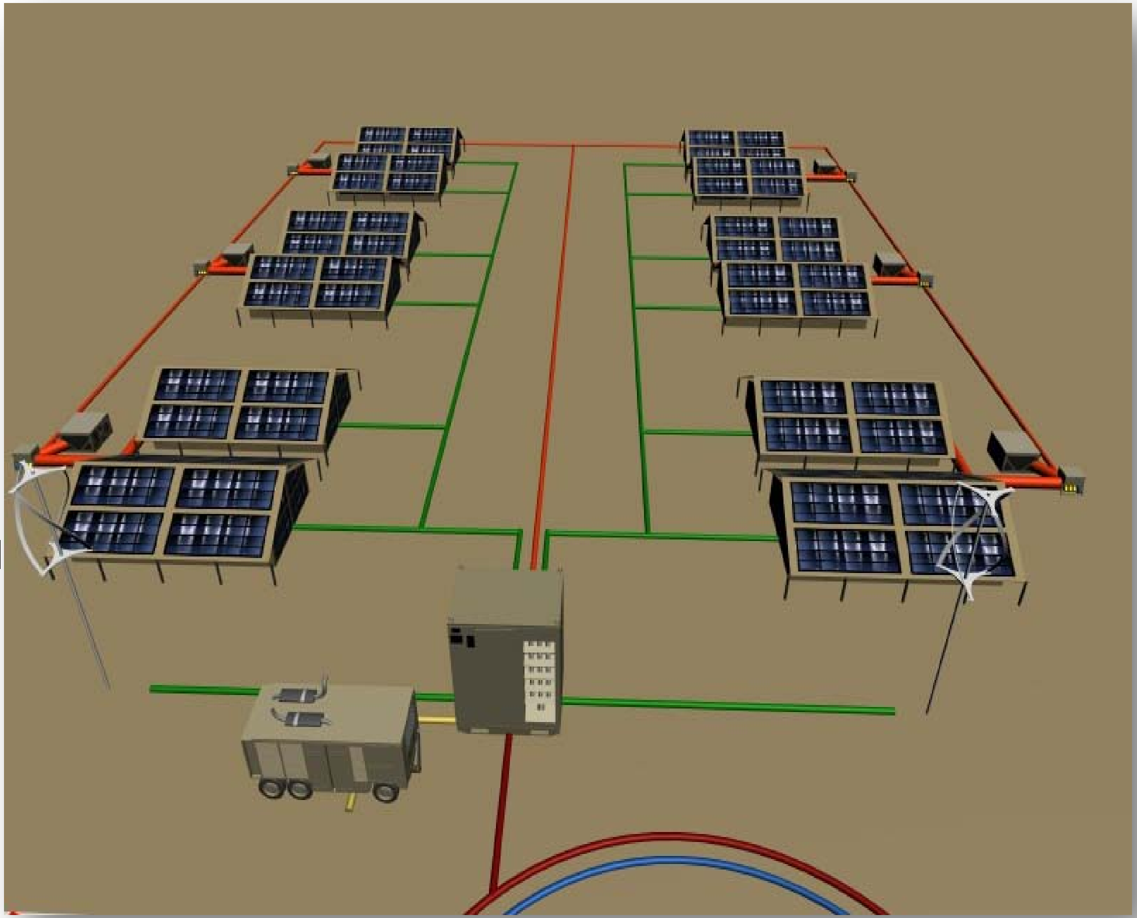
Stand Alone & Integration Modeling

- Each system will be modeled 1st as a stand-alone system. This model will be refined later as physical stand-alone testing is conducted.
- Integration modeling will bring to light how the system should perform once it has been added to the microgrid. Loss budgets will be predicted as well as alternative wiring configurations tested.
- Once the system has been added to the microgrid at least 1 full year of data will be collected to evaluate how the system will operate over a variety of weather conditions.

http://www.istockphoto.com/file_thumbview_approve/5466110/2/istockphoto_5466110-four-seasons.jpg

AIPS 1st Phase

- Phase 1 of AIPS will center around the SDC (Secondary Distribution Center).
- Power will come from 4 sources: solar carport, vertical axis wind turbine, JP8 powered backup generator (MEP 805A), & PEM fuel cell. Some of these sources are on site already and others are in the final stages of construction.
- Addressable breakers and power relays will be used to route power, transition to the backup generator, and shed loads.
- The smart controller will manage all of these functions as well as collect data.



AIPS 1st Phase Data Acquisition & Control

- Smart field controllers will collect sensor data and send control signals.
- System modifications and status updates are available via a touch panel PC.

http://www.ni.com/compactrio/

http://us.fluke.com

- Power Quality Analyzers will assess the impact (Noise, Harmonics, Flicker, etc.) of microgrid components being evaluated.

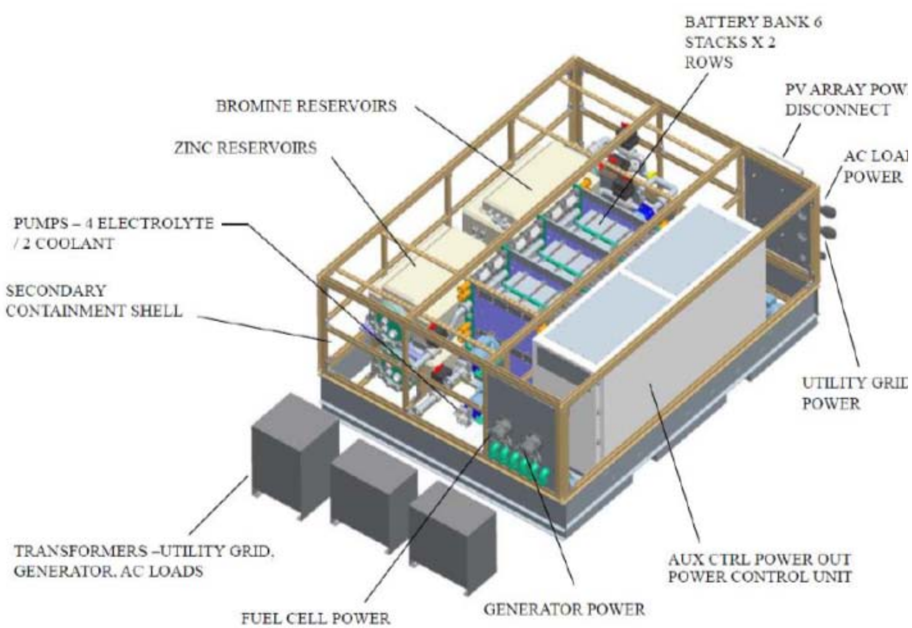
AIPS 1st Phase Primary Power Source "Solar Carport"

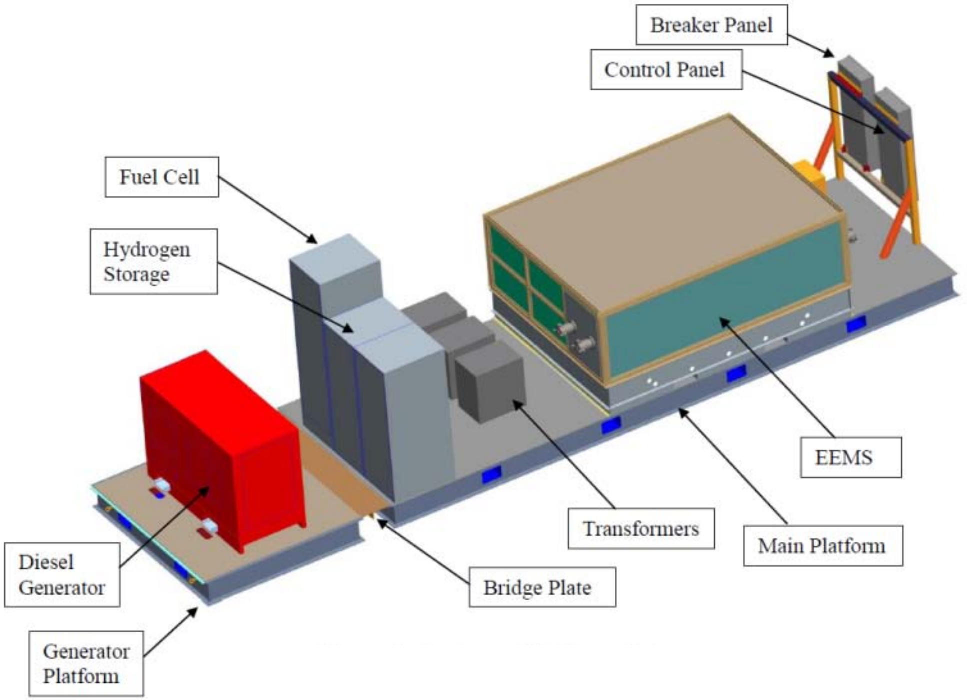
- Solar carport puts out a maximum of 25 kW of power for use in the microgrid test bed.
- Additional power sources for Phase 1 include a PEM fuel cell, 30 kW JP8 generator (MEP 805A), & vertical axis micro wind turbine.

MEP 805A

AIPS 1st Phase Core Pieces

- AIPS will have at its core a revolutionary battery system for energy storage, PEM fuel cell, and other impressive hardware that is coming to AFRL as part of a joint program with APTO (Advanced Power Technology Office) and their contractors.

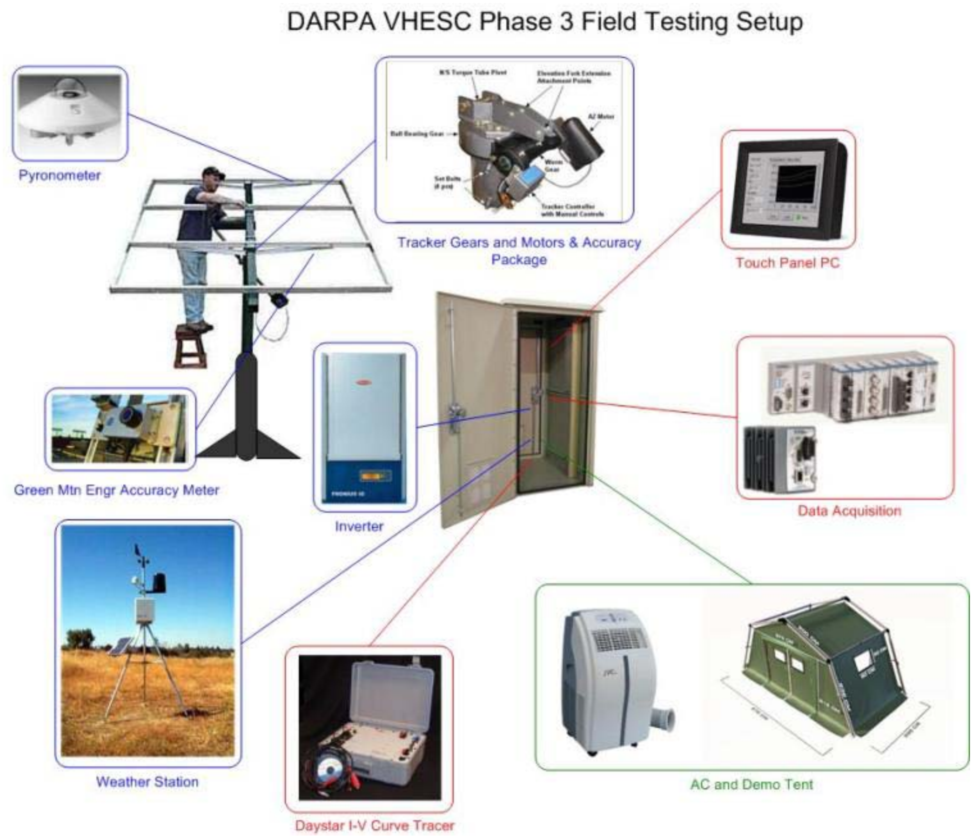




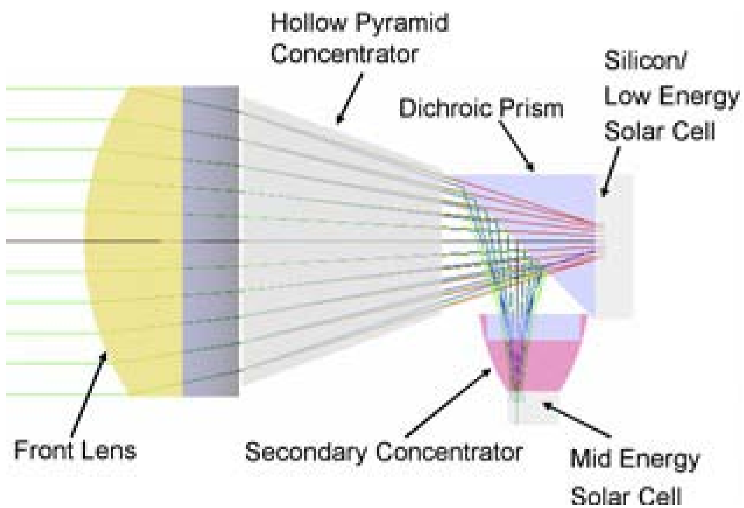
Tipton, Brian, and Loraine Bell. APTO Research, Development, Test, Evaluation and Sustainment Support Next Generation Microgrid with Solar Power and Fuel Cell Technologies. Rep. no. TO2-A013-6. Tyndall AFB: CTC, 2010. Print.

Microgrid Test Bed - DARPA

- DARPA's revolutionary new solar collection system titled VHESC (Very High Efficiency Solar Cell) will be tested in the Tyndall AFB microgrid test bed.



Microgrid Test Setup



http://www.semiconductor-today.com/news_items/2009/SEPT/ENERGYFOCUS_280909.htm

VHESC Cell Concept

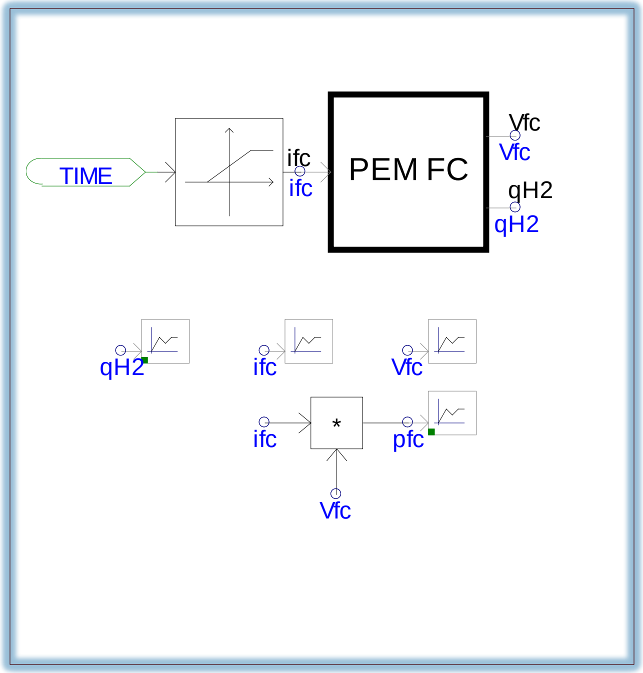
Microgrid Test Bed – AFRL/RXBC

- Revolutionary vertical axis wind turbine developed by the composites group (AFRL/RXBC) will be tested in the microgrid test bed.
- The blades will be stronger and lighter than the best available technologies.
- This system will be able to generate electricity at much lower wind speeds.

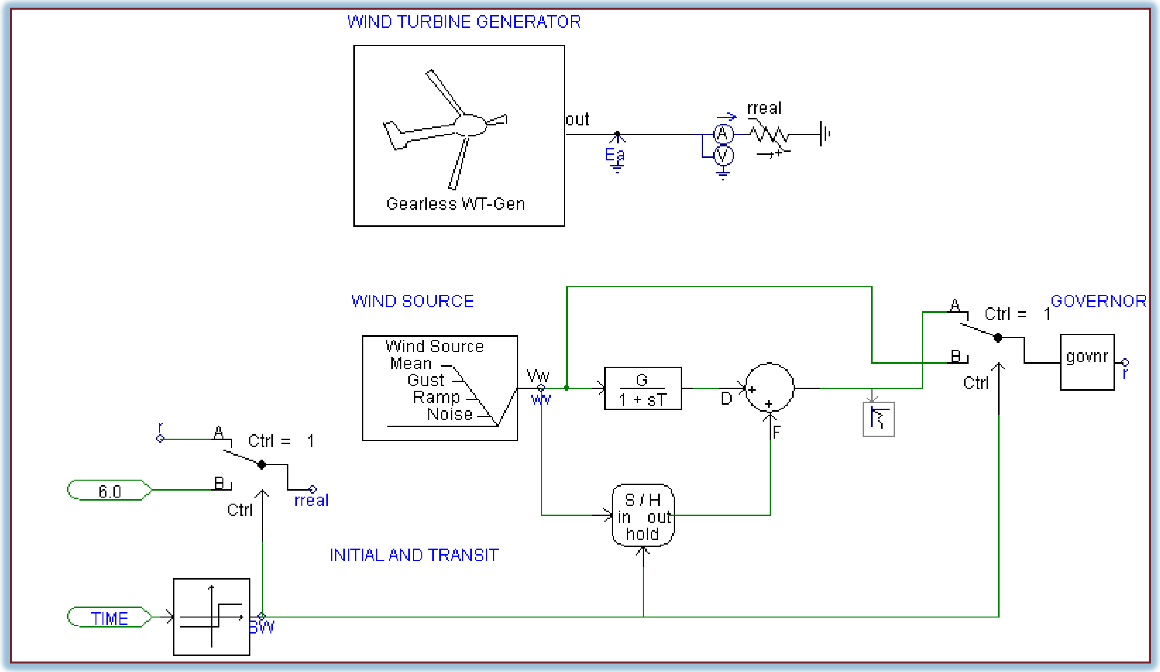
AFRL/RXBC & University of Dayton Aerospace Mechanics Division

Microgrid Test Bed – Missouri University of Science and Technology

- The software model for AIPS will include software models (PSCAD) created for other Air Force programs such as the microgrid project at Missouri University of Science and Technology.
- Work is continuing with models for both the modified wind turbine and revolutionary PEM fuel cell.



PEM Fuel Cell



Wind Turbine

Microgrid Test Bed – Partnerships and Collaborations

Programs

- Missouri University of Science and Technology Microgrid Component Development
- Auburn University, AF Security Forces, & AFRL/RD & RH Laser to PV wireless Power Program
- APTO & CTC Microgrid Demonstration
- DARPA VHESC Field Testing
- AFRL/RXBC Composites Wind Turbine

AUBURN UNIVERSITY

U.S. AIR FORCE ADVANCED POWER TECHNOLOGY OFFICE APTO

CTC Concurrent Technologies Corporation

ARA

MISSOURI S&T University of Science & Technology

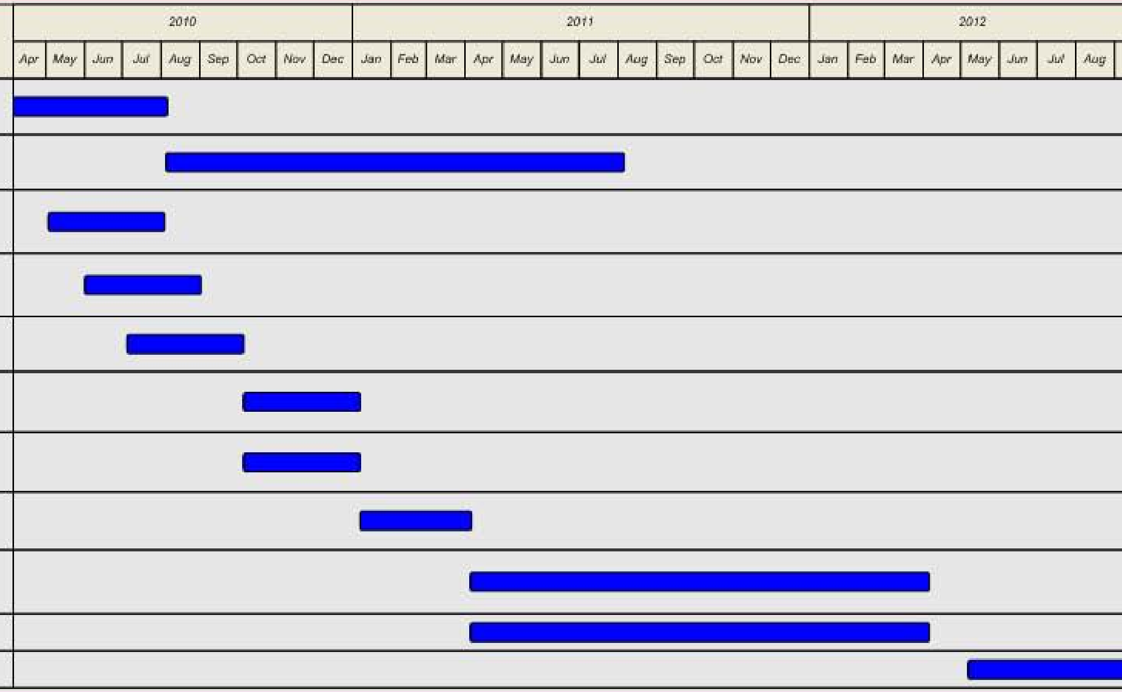
AF SECURITY FORCES CENTER

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

DARPA

Phase 1 Timeline

ID	Task Name	Start	Finish	Duration
1	Install APTO/AFRL Microgrid	4/5/2010	8/5/2010	89d
2	Sustainment of APTO Microgrid (1 year)	8/5/2010	8/5/2011	262d
3	Electrical Design of Phase 1 SDC Level Pass Thru device	5/3/2010	8/3/2010	67d
4	Mechanical Design of Phase 1 SDC Level Pass Thru device	6/1/2010	9/1/2010	67d
5	Develop System at a Glance Software	7/5/2010	10/5/2010	67d
6	Assembly of Phase 1 Pass Thru Device	10/6/2010	1/6/2011	67d
7	Acquire SDC, PDPs, & ECUs for Field Test	10/6/2010	1/6/2011	67d
8	Install Microgrid Components into Tent City	1/7/2011	4/5/2011	63d
9	1 year Sustainment of AFRL Microgrid Phase 1	4/5/2011	4/5/2012	263d
10	Data Acquisition	4/5/2011	4/5/2012	263d
11	Final Report	5/7/2012	9/5/2014	610d



- This chart lays out the timeline to test the 1st phase of the deployed base microgrid.
- The test bed will be put in place 1st so that the 1st phase deployable system can be analyzed and formal recommendations proposed to the CE community.
- Collaboration efforts that will rely on the instrumented test bed will be worked into the schedule and will follow the testing strategy outlined in slide # 3 titled “AIPS Testing Strategy”.

Take Away Thoughts

1. The Advanced Integrated Power System (AIPS) is a fully instrumented research microgrid test bed where new technologies in the power generation and distribution areas will be evaluated.
2. The AIPS is where microgrid components, communication systems, control algorithms, etc. will be modeled, tested, integrated, and evaluated for at least 1 full year.
3. AIPS serves the needs of the warfighter by providing a conduit for smart grid technologies to find their way to the battlefield where reliability, portability, and simplicity are essential.